

# Tidal Hydrokinetic Energy

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September 23, 2010

- **Tidal Energy**
- Challenges
- Northwest National Marine Renewable Energy Center

# Tidal Energy

## Barrage



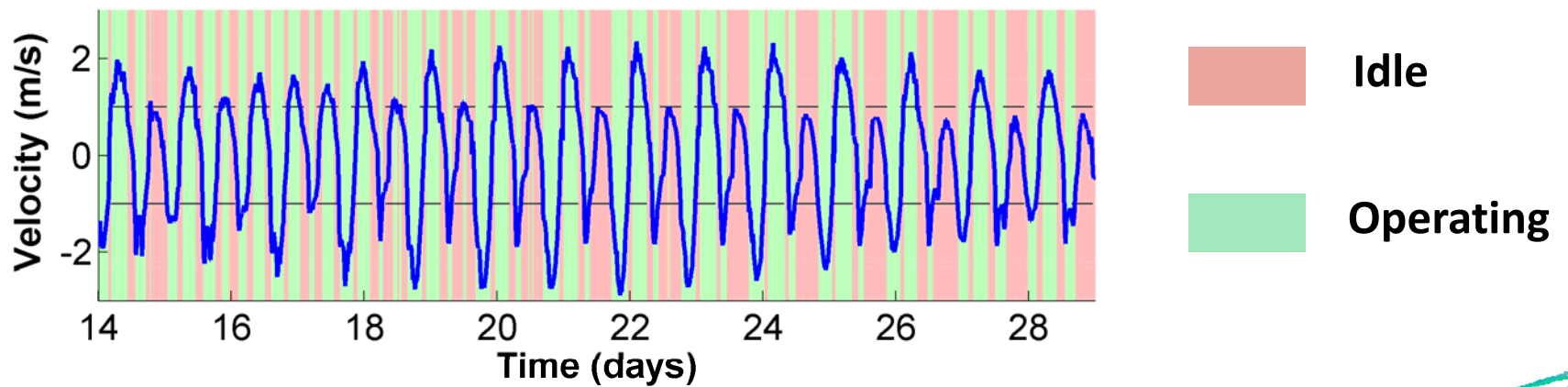
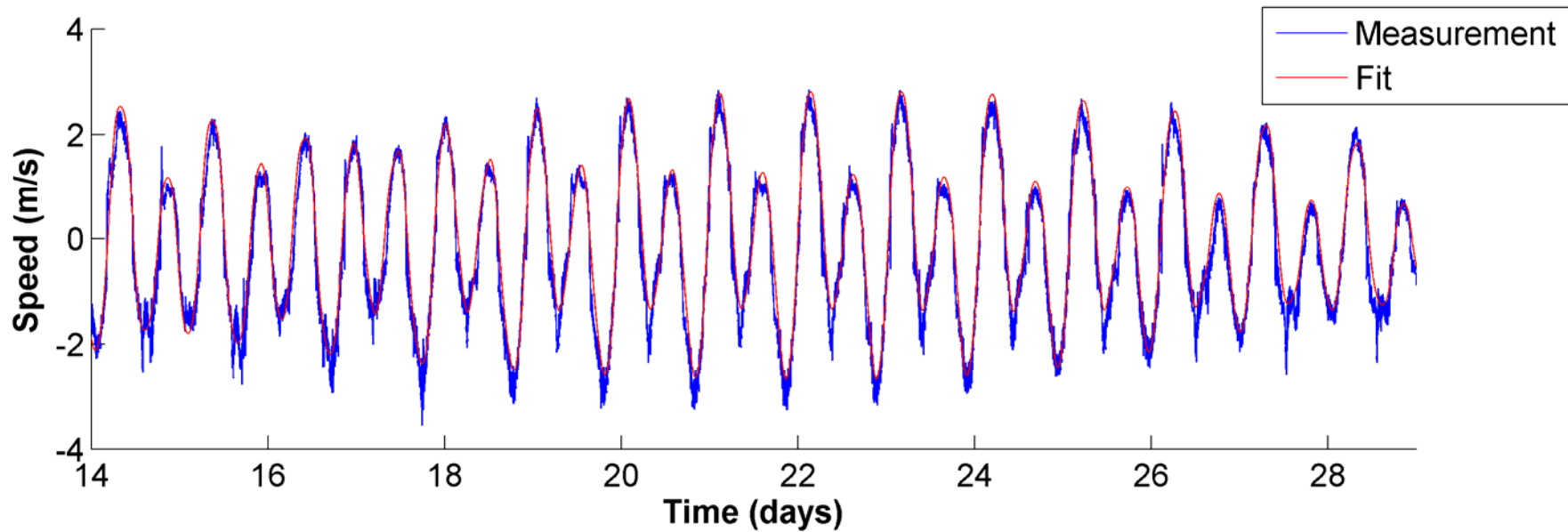
- Comparable to hydroelectric
- Very high cost and environmental footprint

## Hydrokinetic



- Comparable to wind
- Potentially lower cost and environmental footprint

# Tidal Energy Resource



# Other Forms of Marine Energy

Wave



Ocean Thermal

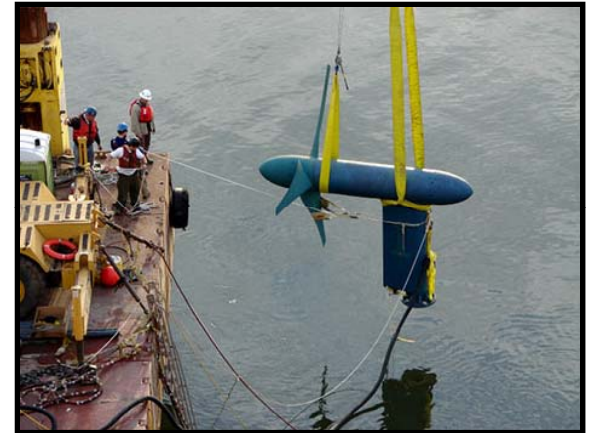
Ocean Current

Offshore Wind

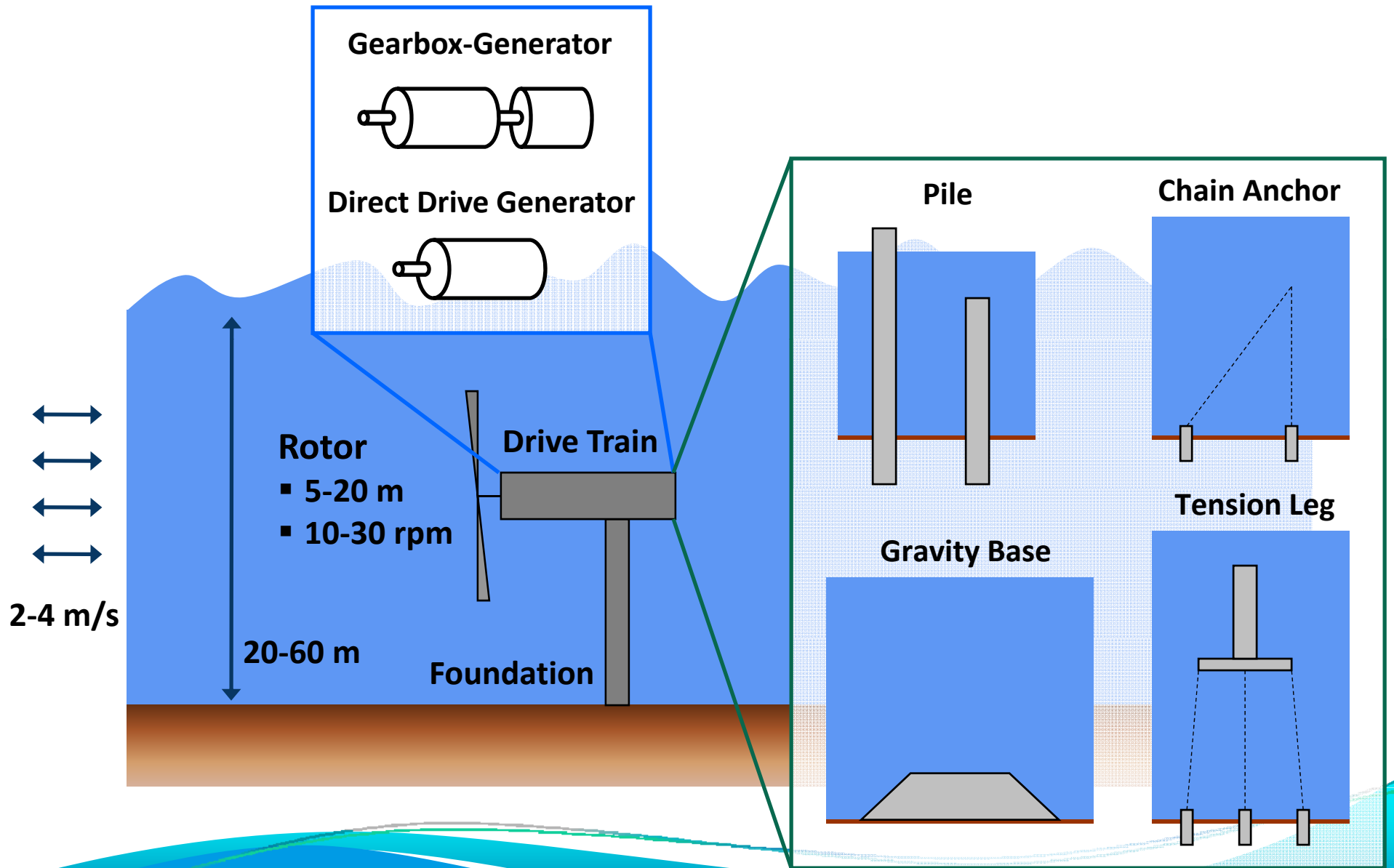




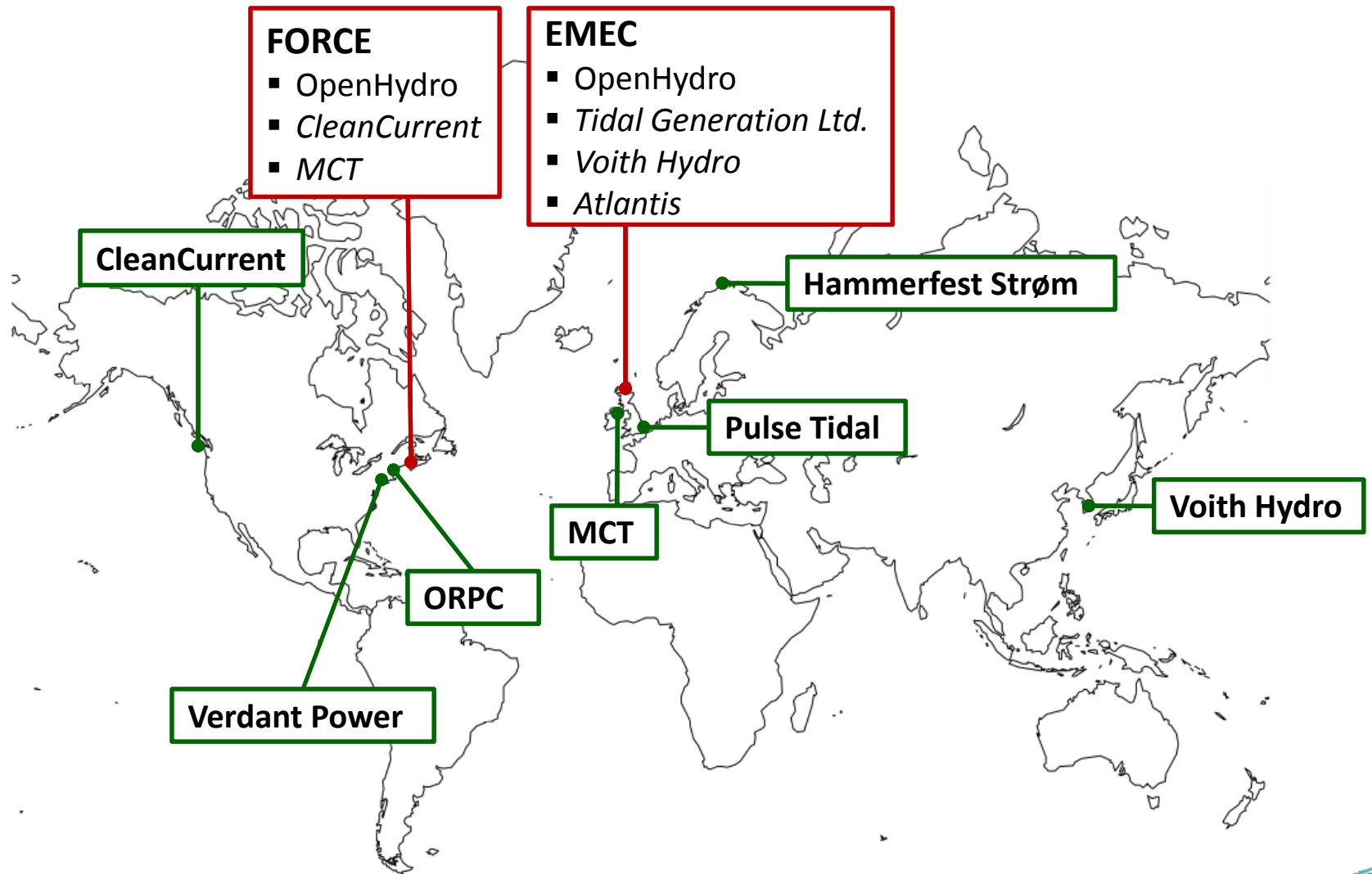
# Tidal Hydrokinetic Devices



# “Typical” Sites and Devices



# Worldwide Demonstrations





# Tidal Energy in Puget Sound



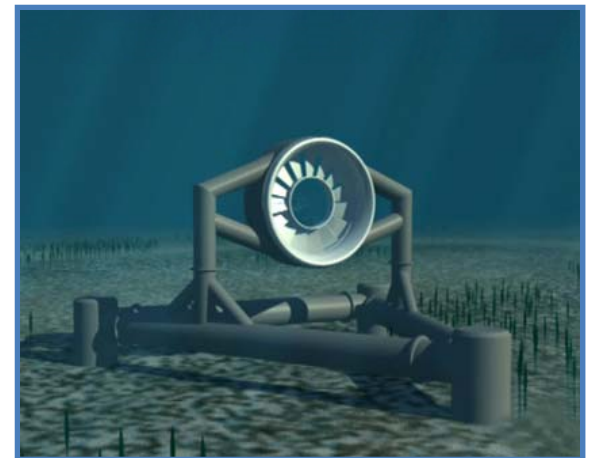
**Race Rocks**  
Demonstration turbine



**Marrowstone Island**  
Demonstration array



**Admiralty Inlet**  
Pilot project



# Motivation

## ■ Local Drivers

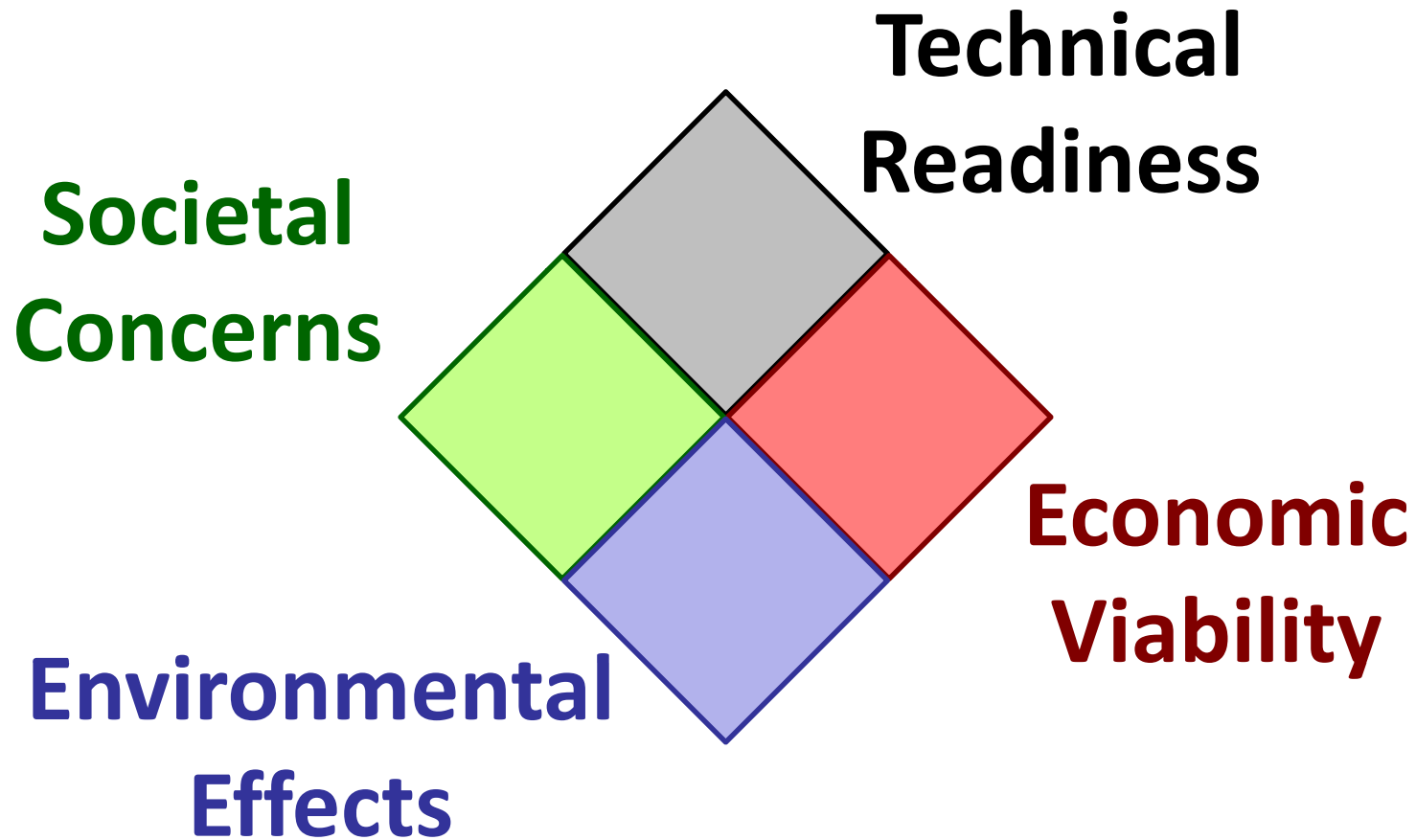
- I-937: 15% renewable energy by 2020
- Limited transmission capacity for new wind energy
- US Navy target of 50% alternative energy by 2020

## ■ National and Global Drivers

- Predictable resource
- No CO<sub>2</sub> emissions
- No visual impact
- Close to load

- Tidal Energy
- **Challenges**
- Northwest National Marine Renewable Energy Center

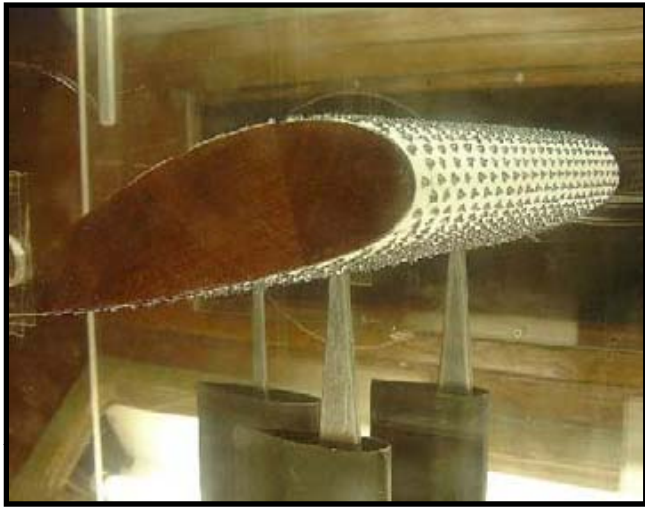
# Tidal Energy Challenges



# Technical Challenges

- **Deep water deployments**
  - Most of the resource is in water deeper than 20m
  - Most wind deployments in water less than 20m
- **Biofouling and corrosion**
- **Long-term reliability**
  - Moving parts in the marine environment
  - 20+ year service life
  - 2+ year service interval

# Survivability and Reliability



Orme, Masters, Griffiths (2001)



316 Stainless – Crevice Corrosion

- **Hydrodynamic performance**
  - Reduced power output
- **Structural performance**
  - Increased loads
  - Metal corrosion
  - Composite aging



# Shallow Water Biofouling Example

Clean Current turbine

15m depth

*6 months* deployment

**Before**



**After**



# Cost of Energy

- **Marine renewables more expensive than terrestrial alternatives**
  - Wave energy: 200-700 \$/MWh
  - Tidal energy: 150-600 \$/MWh
  - Ocean thermal energy: 500+ \$/MWh
- **Several contributors to higher cost**
  - Capital cost for extended marine deployments
  - Operations and maintenance in marine environment
  - Long and uncertain permitting requirements
  - Intensive environmental monitoring requirements

# Potential Environmental Effects

## ■ Effects on aquatic species

- Avoidance
- Aggregation
- Strike
- Entanglement



## ■ Far-field environment

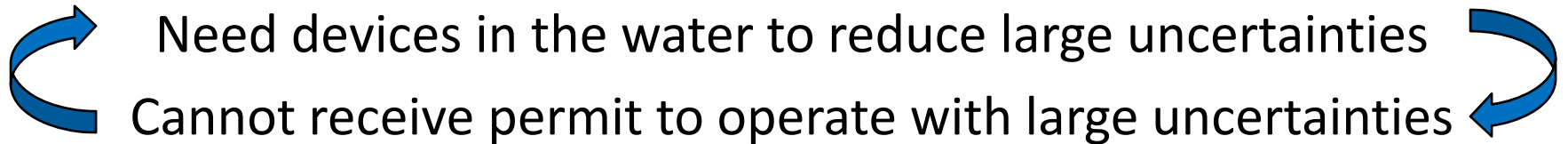
- Circulation
- Nearshore environment
- Water quality

## ■ Near-field environment

- Noise (device, vessels)
- Wake (sediment transport)
- Hard substrate (artificial reef)
- EMF
- Toxicity (coatings, lubricants)

# Barriers to Resolving Uncertainty

- **“Chicken and Egg” Problem**



- **Technology readiness of monitoring**

- “You can only analyze what you can measure...”
- Existing tools focused on stock assessments, not individuals
- Significant overlap with fundamental research needs
- High natural variability in relation to project scale

# Mitigation Trade-offs

**Environment**

vs.

**Economics**

Further from shore less sensitive

Higher cost of energy

Temporary shut-down

Higher cost of energy, financing

**Environment**

vs.

**Environment**

Slack moorings are quiet

Slack moorings pose a high entanglement risk

Taut moorings pose a low entanglement risk

Taut moorings strum loudly



# Existing Uses

- **Tribes**

- Usual and Accustomed Treaty Rights
- Fishing and crabbing

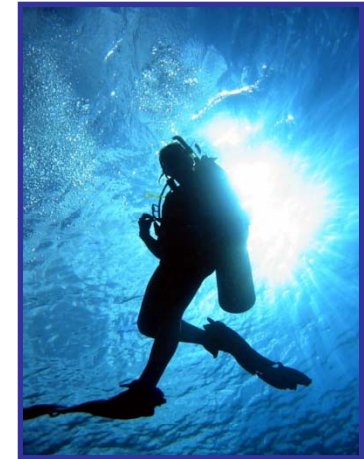
- **Commercial Users**

- Fishing and crabbing
- Shipping

- **Recreational Users**

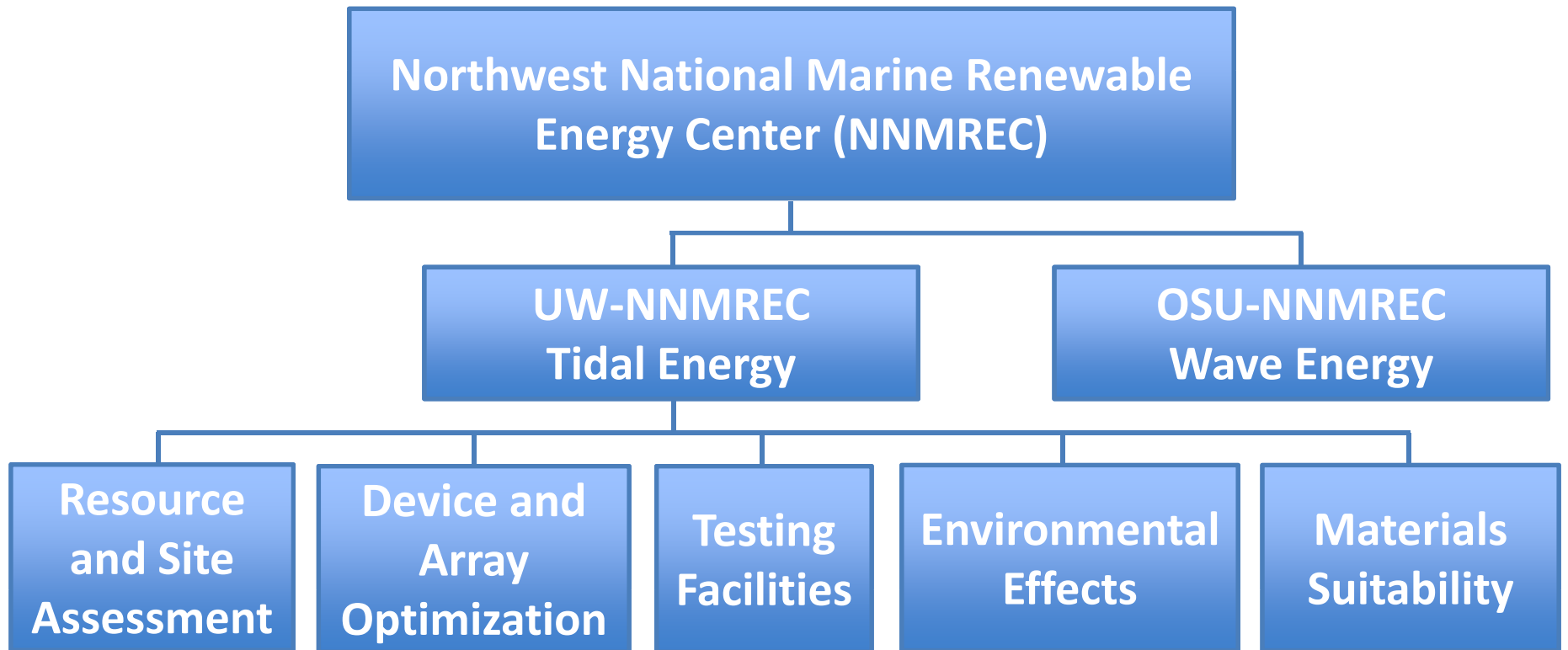
- Fishing and crabbing
- Diving

- **Military**





- Tidal Energy
- Challenges
- **Northwest National Marine Renewable Energy Center**



**8 Faculty members involved**

**10 Graduate student researchers supported**



# Resource and Site Assessment

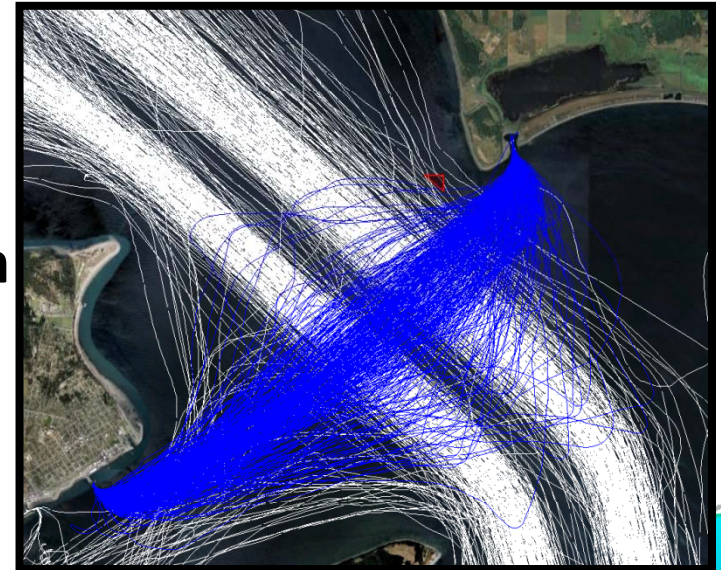


**Seabed Instrumentation**  
*Measurement Tripod*

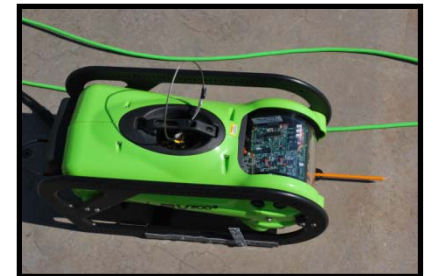


**Shipboard Survey**  
*R/V Jack Robertson*

**Land Observation**  
*AIS Ship Tracks*



# Seabed Characterization





# Sea Spider Instrumentation Tripod

**Acoustic release**  
(redundant recovery)

**ADCP**  
(Acoustic Doppler  
Current Profiler)

**Hydrophone**  
(background noise)

**Programmed for 3  
month deployments**



**CTDO** (conductivity,  
temperature, depth,  
dissolved oxygen –  
partnership with WA  
Dept of Ecology)

**Fish Tag Recorder**  
(partnership with NMFS)

**T-Pod/C-Pod**  
(porpoise clicks)

**Lead Weight**  
(650 lbs)

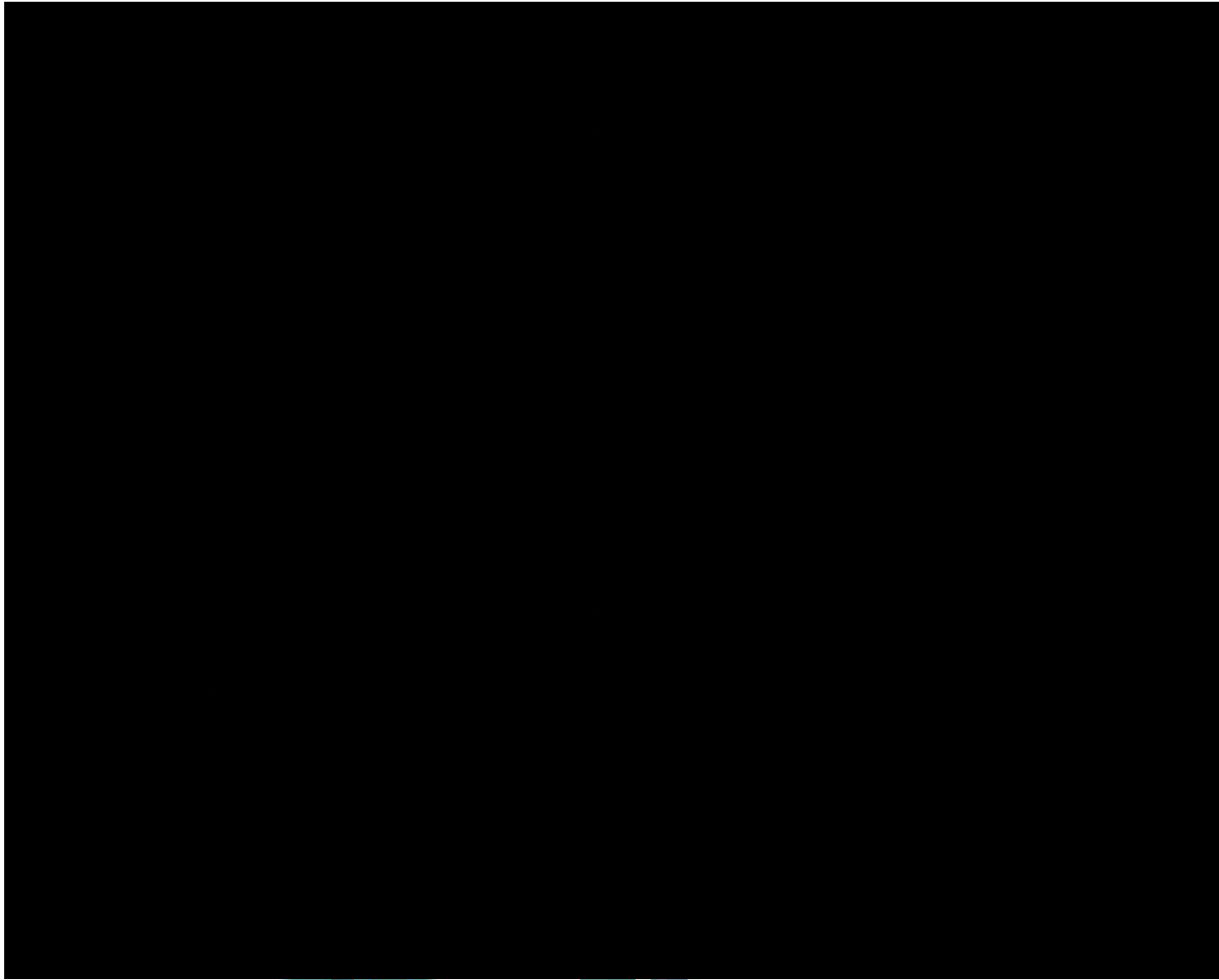
# Deployment Time Lapse

August 15, 2010

Instrumentation Staging



# Rough Deployment



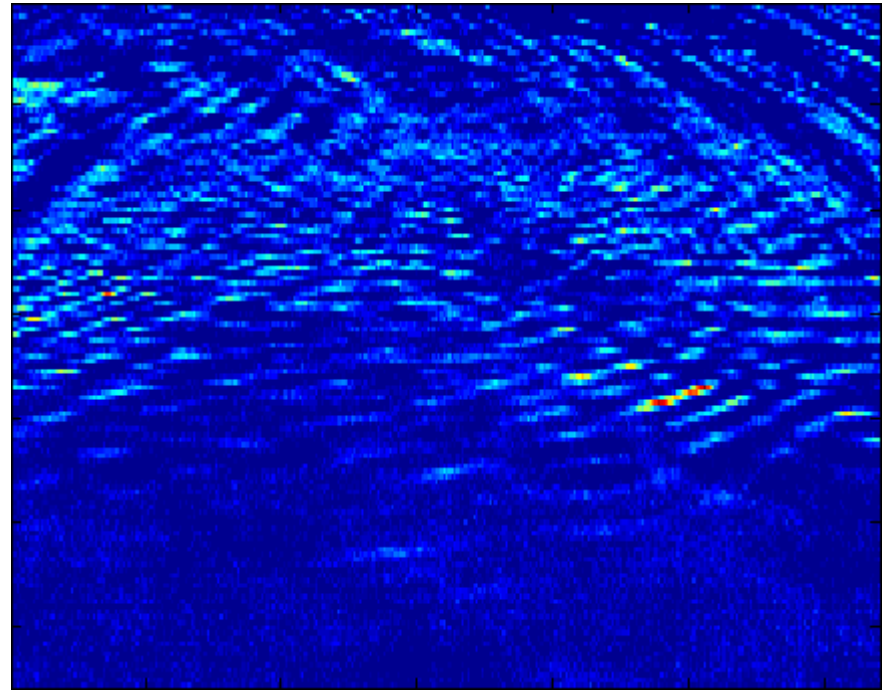
# IR Detection of Marine Mammals

Lime Kiln State Park  
July 5, 2010 at 0350

HD Webcam

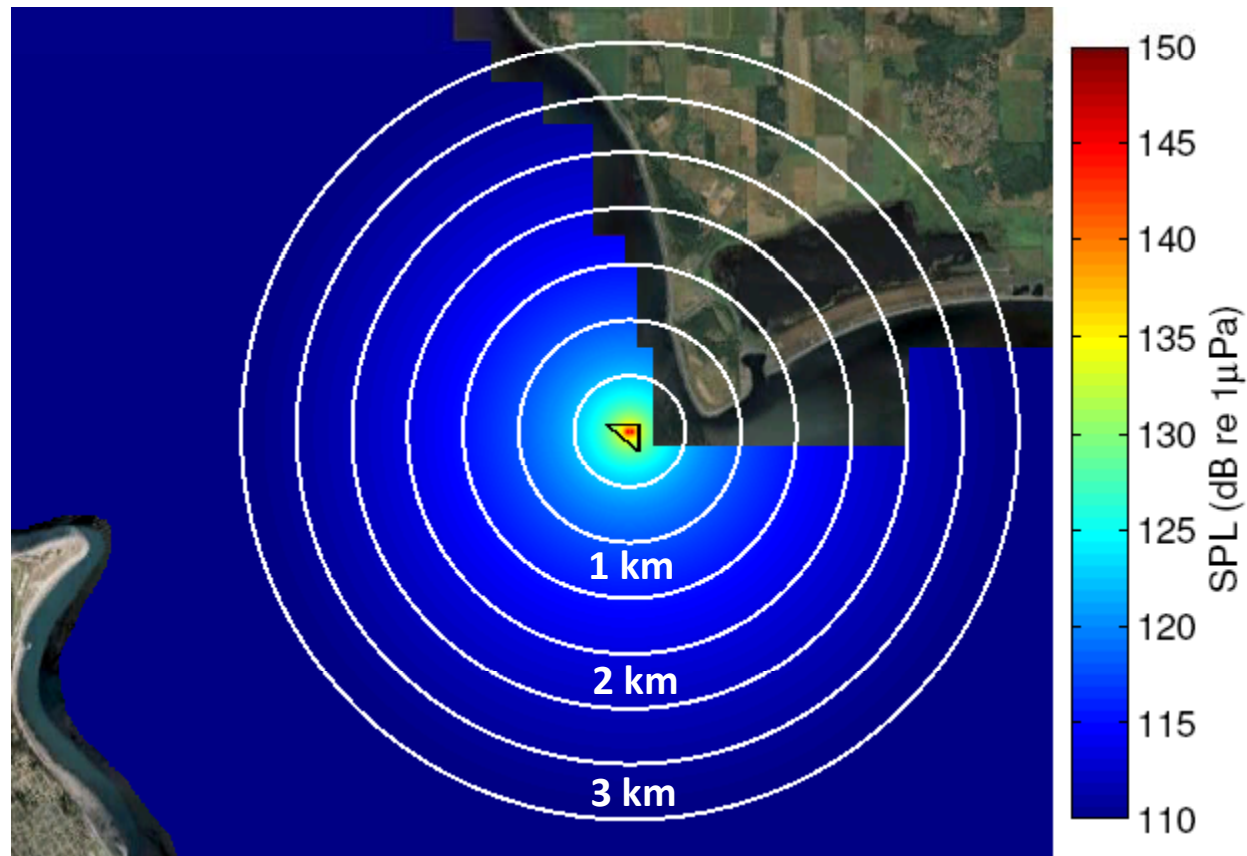


IR Camera



# Turbine Noise

## Two Open Hydro Turbines Northern Admiralty Inlet



# Biofouling Prevention

- **Biocides: “Anti-fouling”**
  - Effective
  - Toxic
- **Low friction: “Foul-release”**
  - Cost
  - Long-term effectiveness

# Deep Water Screening Experiment





# Large Annual Variability





# Composite Aging

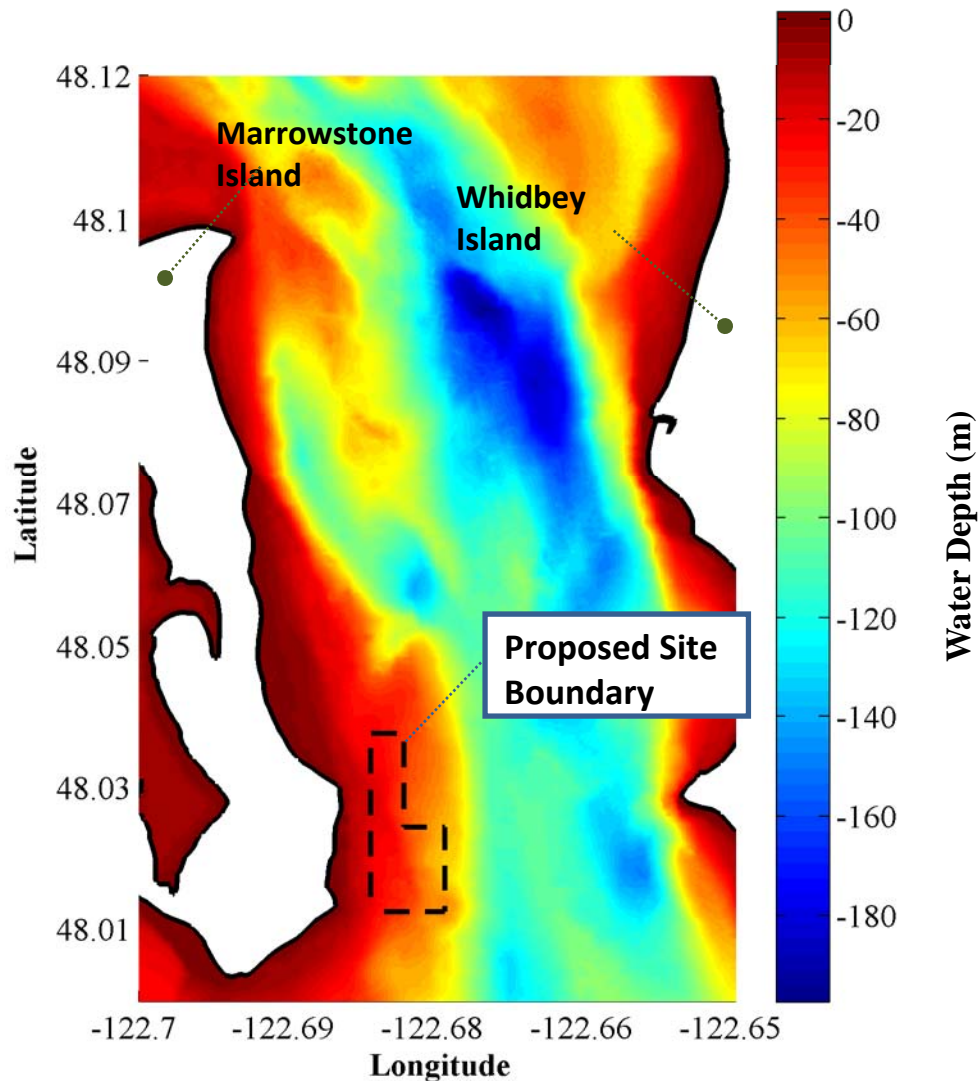


- Water absorption, leading to loss of strength
- *In-situ* screening tests
  - 9 – 18 months exposure
  - Four composite material systems

# Test Platform Goals

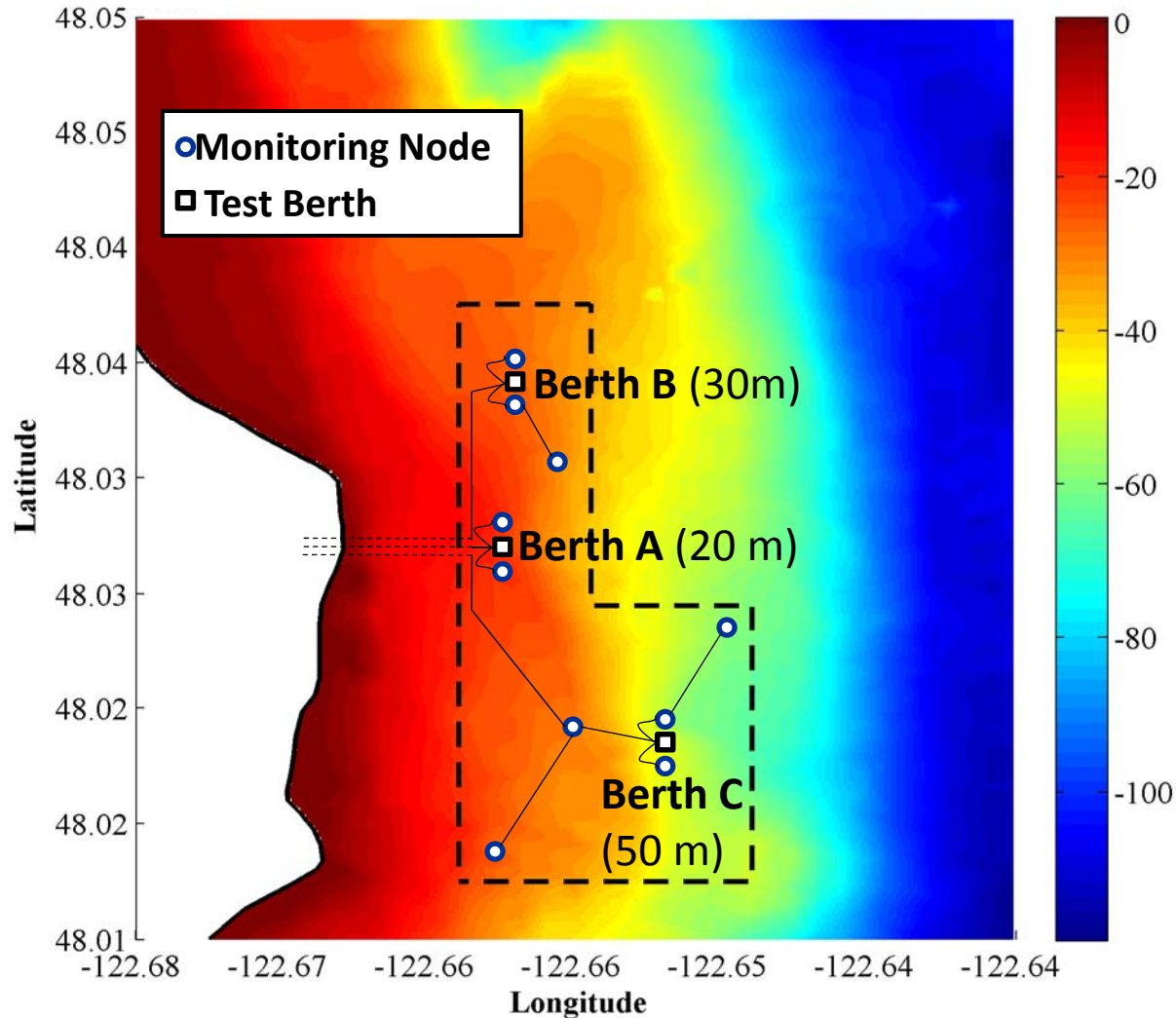
- Provide a fully **instrumented and permitted platform** for testing tidal energy conversion devices.
- Provide **objective performance evaluations** of tidal energy devices in realistic conditions.
- Provide **comprehensive environmental monitoring** to study potential environmental effects of tidal energy conversion.
- **Accelerate commercialization** by reducing development cost and uncertainty.

# Site Characteristics



- **Realistic hydrokinetic resource**
  - Peak currents  $\sim 2.5$  m/s
- **Supports range of devices**
  - Depth varies from 20m to 50m over 1 km distance
- **Full range of aquatic species present**
  - Fish
  - Marine mammals
  - Diving seabirds

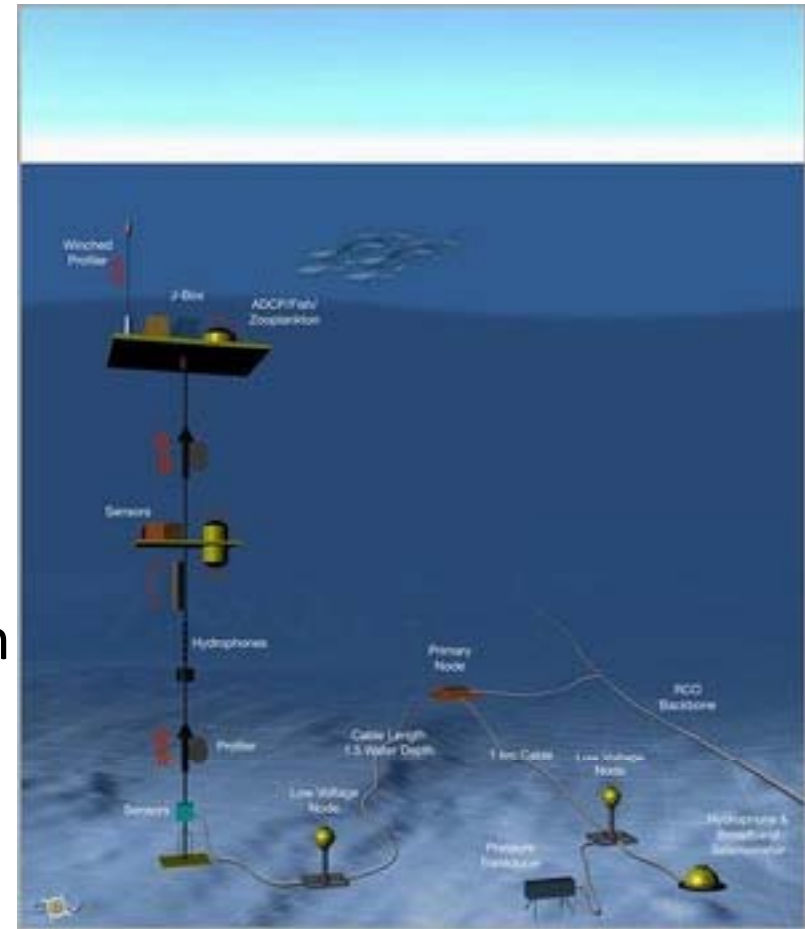
# Infrastructure Concept



- Grid connection
- Environmental and performance monitoring nodes
- Plug and play foundation
- Power and data “sockets”

# Leveraging Infrastructure

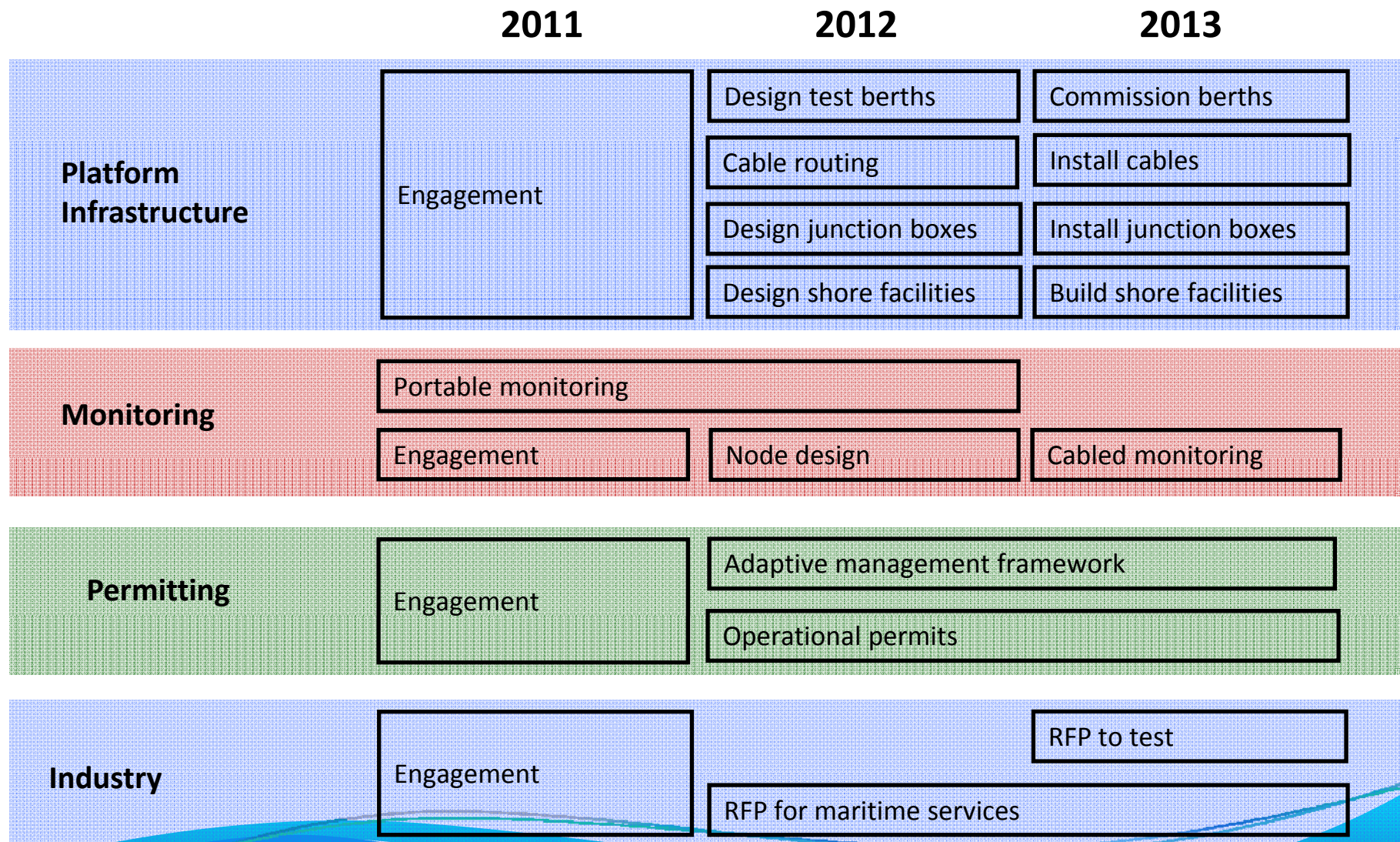
- Build on NSF Ocean Observing Initiative
- Fiber optic to Ethernet: real-time observations
- Robust nodal architecture, "daisy chain" interconnections
- Simple retrievals for service/upgrade (independent from tidal device maintenance)
- Potential to integrate proven technologies next to beta



*UW-APL Regional Scale Nodes project*



# National Tidal Energy Platform





# Conclusions

- Tidal energy is not a “silver bullet”, but will be regionally important.
- Significant challenges must be overcome before commercial development.
- Opportunity for universities to solve these problems and train first generation of marine energy engineers.

# Thank You!

To learn more about tidal energy, visit:  
<http://depts.washington.edu/nnmrec>